Analysis of the Difference between SRTM and GLOBE Elevation Data for Calculating Television Protected Contours

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1. Summary

In this document I study the net impact of using different digital elevation data within the algorithm for calculating geographic contour distances for television stations. I have found that there is no measurable difference in the geographic contours calculated using the SRTM and GLOBE elevation data.

2. Discussion

The US Federal Communications Commission (FCC) describes a method to calculate a geographic protected area or contour using R-6602 curves. (See 47 CFR 73.684 and 47 CFR 73.699.) To calculate a television transmitter's geographic contour you must calculate several key parameters about the transmitter's environment, including the antenna height above average terrain. A digital elevation model provides the information required to calculate average terrain.

2.1. Calculating Contour Distance

To create a geographic protected contour the distance calculation is done in every radial direction, from 0 to 360 degrees. The actual method to calculate the contour distance requires a 2-dimensional interpolation, whose details are outside the scope of my study. To calculate protected contour distances I used the Key Bridge Java software library "FSCurves" which already includes the method getContourDistance() that implements the R-6602 methods with the inputs

- channel: is a Television channel between 2 and 63

- haat: is the antenna height above average terrain in meter

- erp: is the television transmitter power in dBm

- percentTime: is 50 or 90 for analog or digital F-curve values

and returns the value

- distance: is the distance to the protected field strength contour in km

Of the input values only the HAAT is dependent upon an elevation model.

2.2. Calculating HAAT

Height Above Average Terrain, or HAAT, is described in the CFR and conveniently explained by the FCC at http://www.fcc.gov/mb/audio/bickel/haat_calculator.html. "A HAAT value is determined by taking 50 evenly spaced elevation points (above mean sea level [AMSL]) along at least 8 evenly spaced radials from the transmitter site (starting at 0 degrees [True North]). The 50 evenly spaced points are sampled in the segment between 3 to 16 km along each radial. The elevation points along each radial are averaged, then the radial averages are averaged to provide the final HAAT value."

To calculate the HAAT and radial HAAT I used the Key Bridge Java software library "ElevationProfile", which includes the method getRadialAverageTerrain()

with the inputs

- GeoCoordinate: is a geographic coordinate object encapsulating a latitude and longitude

and returns the value

- TreeMap<Integer, Double> radialAverageTerrain: is an array object containing average elevation values for 360 radial directions

and the method getAverageTerrainElevation()

with the inputs

- GeoCoordinate: is a geographic coordinate object encapsulating a latitude and longitude

and returns the value

- averageTerrain: is the average elevation height in meters above mean sea level (AMSL) at the input geo-coordinate.

The method getAverageTerrainElevation() is described as a simple extension of getRadialAverageTerrain() and provides the average of the radial averages.

2.3. Elevation Data

SRTM and GLOBE data were accessed using the Key Bridge Java software libraries "SRTM3_ElevationModel" and "GLOBE_ElevationModel", which both implement the "ElevationModel" Java interface method getElevation() with the inputs

- GeoCoordinate: is a geographic coordinate object encapsulating a latitude and longitude

and returns the value

- elevation: is the elevation, in meters above mean sea level, at the specified location

For my investigation I used the SRTM-3 data, which provide 3-second resolution. The GLOBE data provides 30 second resolution.

2.3.1. SRTM Digital Elevation Data

SRTM stands for Shuttle Radar Topography Mission and is described in its documentation *"The SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial Intelligence Agency, as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometry."*

### 2.3.2. GLOBE Digital Elevation Data

The Global Land One-km Base Elevation Project (GLOBE) Task Team was established by the Committee on Earth Observation Satellites. It was part of Focus I of the International Geosphere Biosphere Programme - Data and Information System.

2.4. Differences between SRTM and GLOBE Data

The main difference between SRTM and GLOBE data is resolution. SRTM data resolution is 3 arc second per pixel or approximately 0.09 km while the GLOBE resolution is 30 arc second per pixel or 0.93 km. Each GLOBE pixel therefore represents 100 SRTM pixels (a 10 x 10 grid) and can be interpreted as an average SRTM elevation value across those 100 pixels.

3. My Hypothesis

When measuring over large distances I expect that GLOBE and SRTM elevation values should give matching answers while at fine resolutions the elevations may be different, especially in rough or mountainous terrain. This principal is illustrated below:
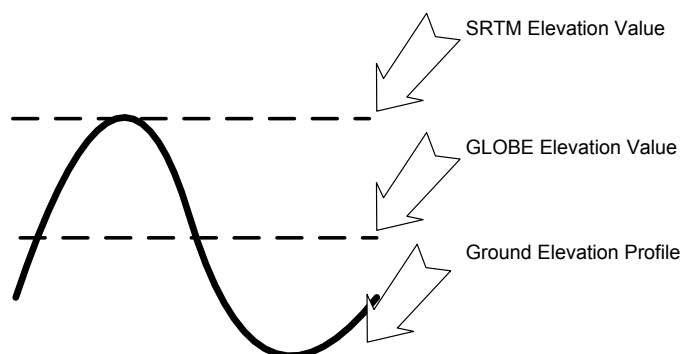
I also expect that because television stations are more likely to locate on mountain tops or local high-points that SRTM elevation value may be higher than GLOBE elevations for the television stations in the CDBS database.

Finally, I propose that any elevation differences will blend together and converge to zero during the calculation of protected contour distances and that there will be no significant difference in the final answer provided by the two sets of elevation data.

4. Elevation Measurements

For all of the following measurements I calculated the difference in elevation between SRTM and GLOBE data as SRTM value minus GLOBE value, so a positive difference means the SRTM elevation is higher than the GLOBE elevation.

4.1. Ground Elevation

First I calculated the ground elevation for all television stations in the CDBS database using both the SRTM and GLOBE elevation models. The results were analyzed and the difference in elevation (SRTM minus GLOBE) was plotted in a histogram.

The maximum and minimum difference in elevation were -318 meters and +536 meters, and my analysis showed that the SRTM elevation set was on average +47.2 meters higher than GLOBE.

Difference between SRTM and GLOBE Ground Elevation of TV Transmitters in CDBS
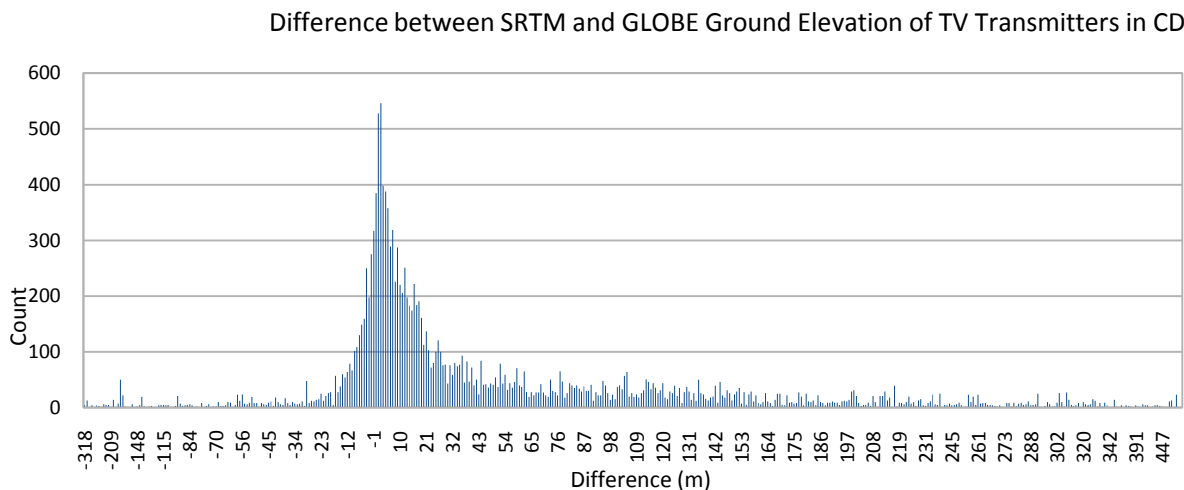
I then plotted and analyzed on Google Maps a random sample of 50 television stations with difference values above 100 meters to understand why the difference value would be so large and to confirm my hypothesis about mountainous terrain. Of the 50 sites I examined all were located in very rough terrain, with all either at the peak of a mountain, on the slope of a mountain, in a valley or in a city surrounded by nearby mountains.

I therefore believe my first hypothesis is correct: that measurement from a more precise elevation model show higher elevation values for sites that locate on top of mountains and hills.

I then extended the algorithm to sample eight points in a regular "box" pattern around each television transmitter by moving the geographic coordinates up and down, left and right by one arc minute (approximately 1.85 km). This increased the sample size by a factor of 9. The results were analyzed and the differences plotted in a histogram.

The maximum and minimum difference in elevation increased to -560 meters and +671 meters. However, my analysis showed that the SRTM elevation bias reduced from +47.2 meters to +5.3 meters. This is also consistent with my hypothesis about precision, as the "box" pattern sampled

an extended geographic coverage area around each transmitter and reduced the bias for mountaintop locations.

Elevation difference with extended "box" sampling
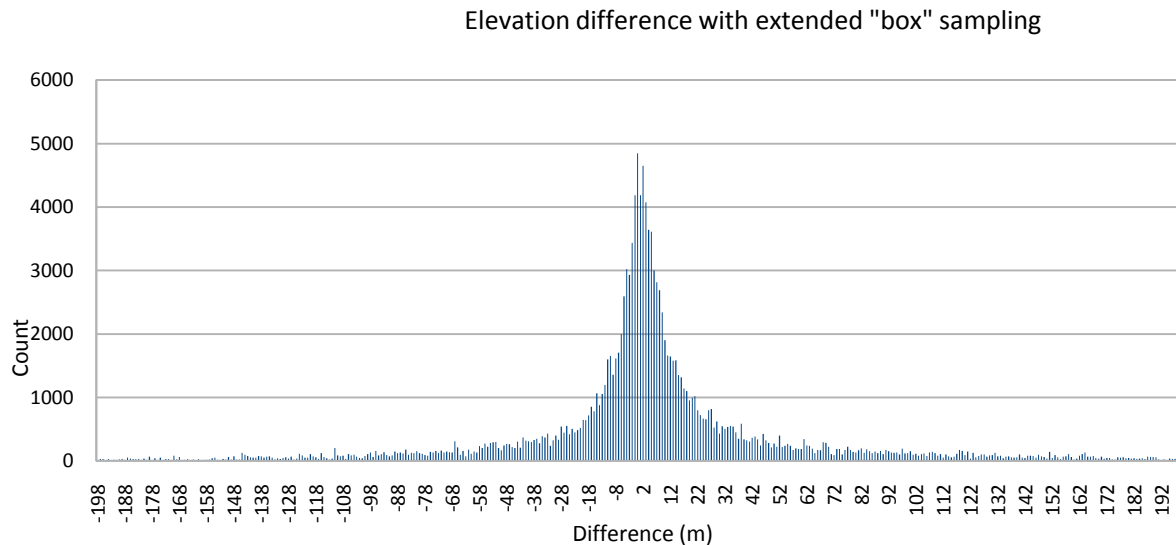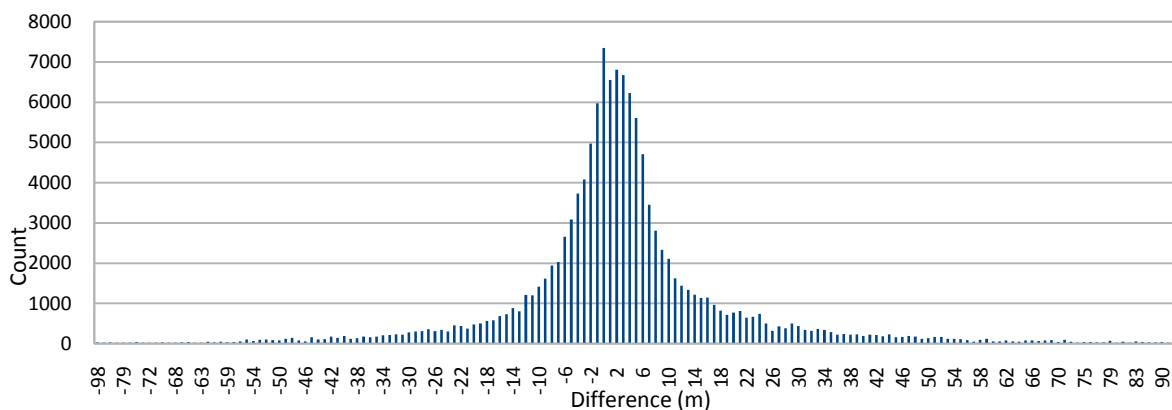

4.2. Radial HAAT

I then calculated the Radial HAAT for each television transmitter in the CDBS database using both elevation models and calculated their difference.

My hypothesis about elevation model precision predicts that the average difference should approach zero and that the distribution histogram should tighten.

The results were analyzed and the differences plotted in a histogram. The maximum and minimum difference values were -590 and +200 meter with an SRTM elevation bias of +2.73 meter.

To understand why the negative differences were not converging like the positive differences I sampled 10 random transmitters with difference values below -250 meters. As before, most all of the cases included very rough and steep terrain, where the SRTM data precision showed mountaintop (or near) elevation while GLOBE showed mid-range elevations. I further analyzed the results and discovered that 99% of all stations have Radial HAAT elevation difference values less than 100 meters, confirming my hypothesis that the values should converge with increased average sampling and that only a small number of stations with unusual terrain were not converging.

Difference in Radial HAAT Average Values (8 radials per transmitter)

4.3. Average Terrain

I then calculated the average terrain elevation for each television transmitter in the CDBS database, which is the average of the radial HAAT values from before. As expected, the sharpness of the distribution (sigma) increased, and 99% of all difference values were less than +/- 45 meters (from +/- 200). The average elevation difference was +2.72 meters (from +2.73).

However, approximately 47 stations identified earlier continued to exhibit very large elevation differences outside the 99 percentile, with negative difference values between -100 and -512 meters.

Difference in Average Terrain Elevation for TV Stations in CDBS
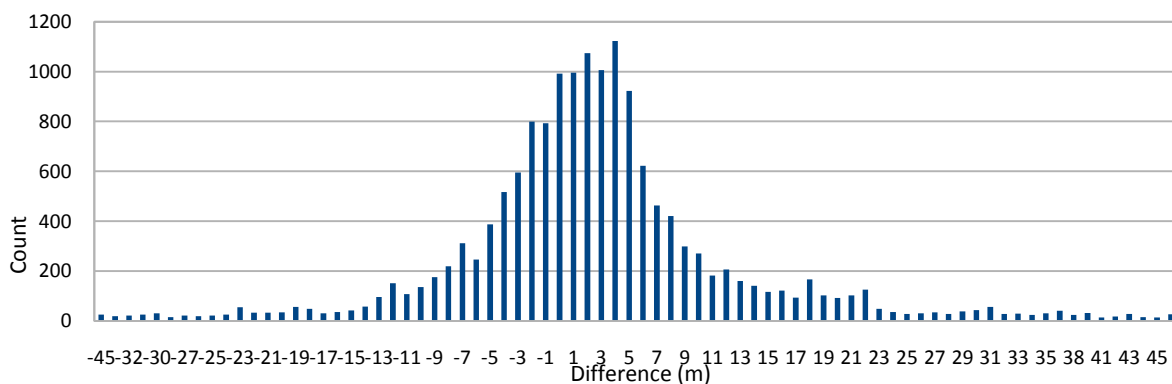
## 4.4. Elevation Measurements Conclusion

My interpretation of the above analysis is that for television stations in the CDBS database the SRTM elevation data produces an average terrain elevation that is on average 2.72 meters higher than when the GLOBE elevation data is used, and for a very few (less than 1%) stations located in very mountainous terrain the difference in elevation measurements is significant (greater than 100 m).

5. Contour Measurements

I then investigated whether the +2.72 meter bias would impact a contour calculation or whether it any differences would cancel themselves out.

5.1. Range of ERP Values

To quantify the net impact of a +2.72 meter elevation bias from the SRTM data on television protected contour distances I needed to know the available range of input values for ERP present in the CDBS database. This was extracted from the database with a simple query and shows the ERP (dBm) ranging from -41 to +44. The distribution is plotted below.
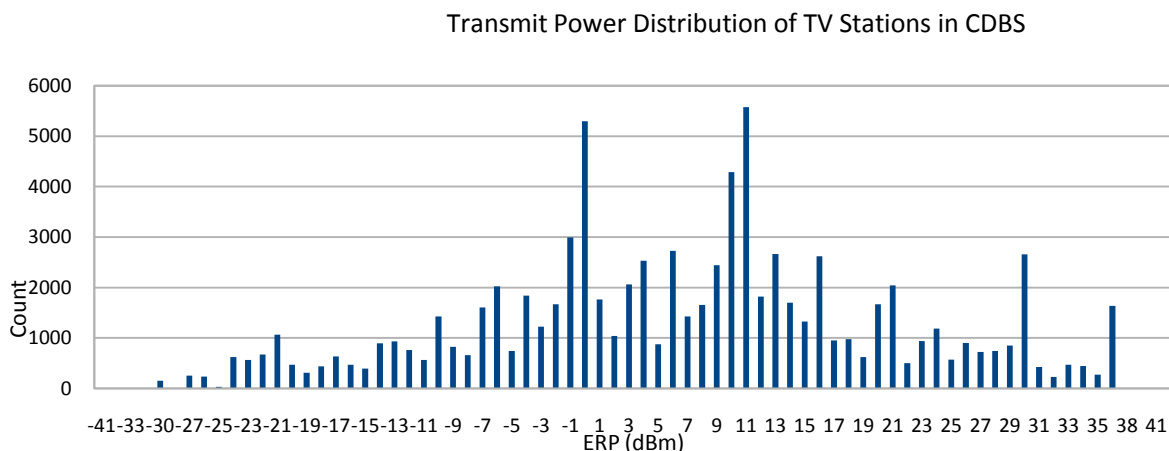

5.2. Radial Contour Distances

Using the Key Bridge "FSCurves" library I calculated a set of contour distances for all stations in the CDBS database. My procedure was to fix the channel and percent time variables to a typical value and allow the ERP to range from -41 dBm to +44 dBm in 1 dBm steps and for the HAAT to range from 30 meters 1524 meters (the allowable range) in 1 meter steps. I chose channel 25 as a representative channel, and a percent time of 50% since most television transmitter records in CDBS are still analog. I then repeated the same set of calculations while increasing the HAAT value by +2.72 meters. I then calculated the difference in contour distances, and finally calculated the difference in geographic contour areas.

The difference in contour distances was greatest for small HAAT values where the +2.72 meter increase was a higher percentage of the total HAAT value. For example, for the smallest HAAT value of 30 meters, the offset represented almost a 9% height increase.

For each HAAT value I recorded the average contour distance and the difference. Average contour distance ranged from 29 to 105 km while the difference ranged from 0.74 to 0.02 km. As a percentage of contour distance, the difference ranged from 2.3% to 0.02%.

I then plotted the average difference in contour distance versus HAAT with a +2.72 meter offset.

Average Contour Distance (km) and Difference (%)
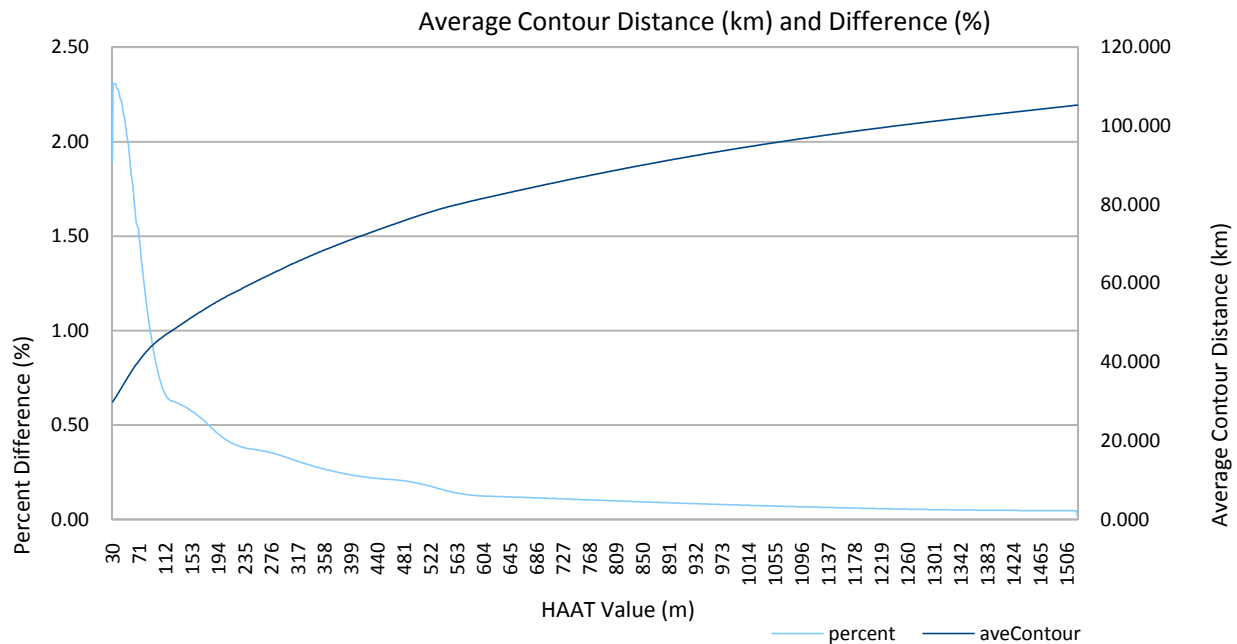
5.3. Geographic Contours

Finally, I calculated the difference in geographic area between contours calculated using the SRTM and GLOBE elevation data.

For each television station in CDBS I calculated the stations ground elevation, radial HAAT, and radial contour distance for each direction in 360 degrees. I then translated the radial contour distances into a spatial geometry using the Key Bridge library "GeoUtils", which contains the method getPolygon() with input values

- TreeMap<Integer, Double> radialContour: is an array of contour distances for each radial

- GeoCoordinate is a geographic coordinate object encapsulating a latitude and longitude of the station

and returns the value

- Geometry: is a properly formatted polygon object

Using the "GeoUtils" library I created a geometry object representing the geographic protected contour for each television station in the CDBS database using contour distances calculated with the SRTM elevation data and I recorded the area enclosed by each geometry object. I then repeated the process using the GLOBE elevation data. Finally, I calculated the difference between geometric areas enclosed within the two geometric objects for each television station. A plot of the 360 geographic coordinates was created to view the geographic contour points and an example screenshot is shown below.

Television id[1188608] callsign[WSTE-DT] ch
[00/07] svc[TS] hgt[-102.9,   67.1] ant[68756][D]
loc[18.04580,-66.65406]

6. Study Results

For 100% of the television records in CDBS the area calculated using the SRTM elevation data exactly matched the area calculated using the GLOBE elevation data. This was confirmed to the precision of 9 decimal places.

I therefore conclude that my original hypothesis is correct: that any differences in elevation average to zero and that there is no difference when using the SRTM (3 second) or GLOBE (30 second) data when calculating television contours.

6.1. Discussion

My investigation showed a +2.72 meter bias for television station elevations for SRTM over GLOBE data. The net impact is that television stations in rough or mountainous terrain will possibly have higher ground elevation values when using SRTM data than with GLOBE data. However, all other radial elevation values will also be similarly affected and cancel out. This is confirmed by my final area calculations, where no difference could be detected in the geographic areas of contours calculated using SRTM and GLOBE elevation data.

Finally, elevation data should not be mixed when calculating contours. Instead, all the elevation measurements should be taken only from one data set as the SRTM and GLOBE data produce difference heights for specific points. Using different data sets in a calculation could accumulate bias instead of canceling it and create an error in the final result.

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